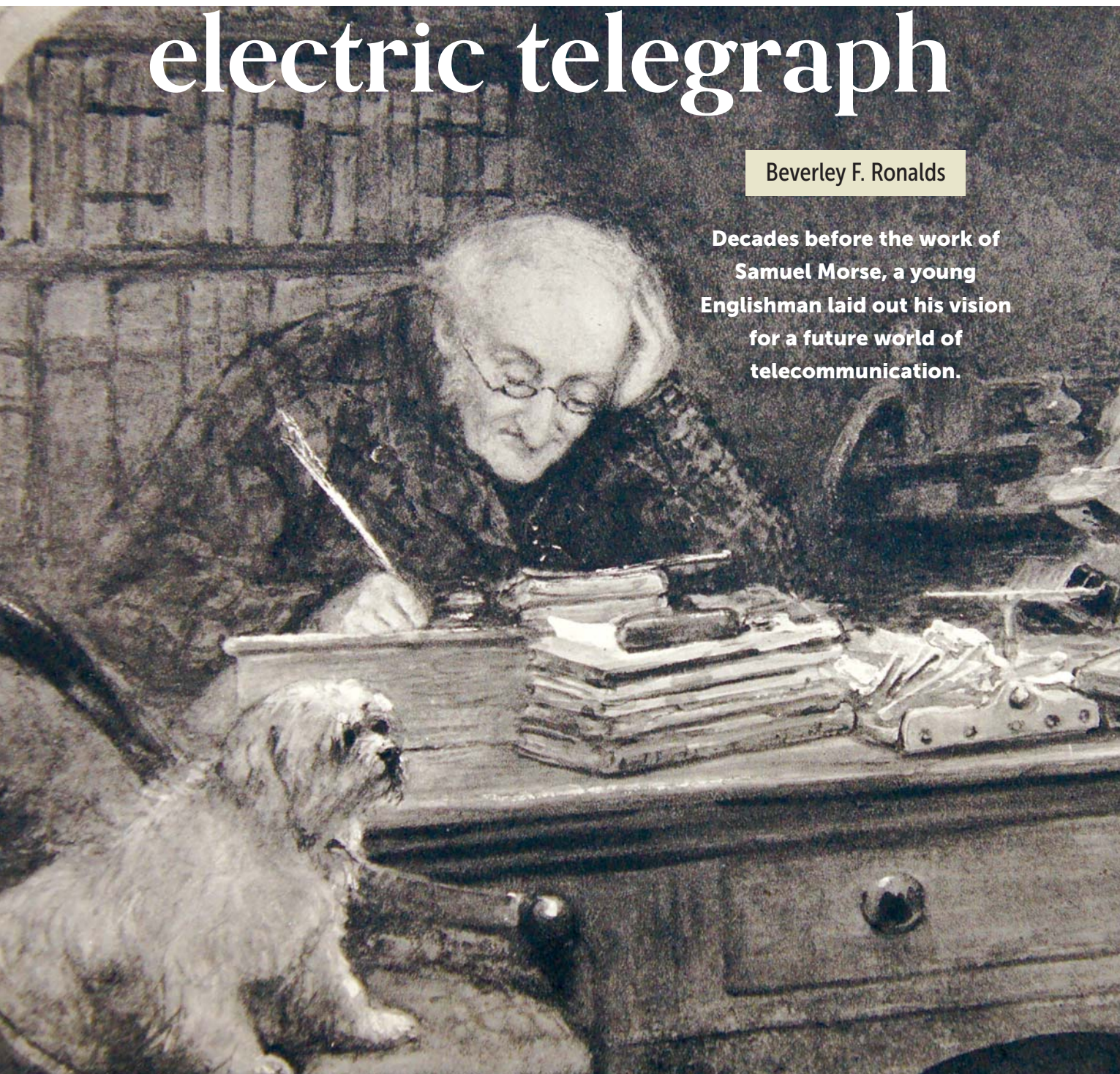


The bicentennial of Francis Ronalds's electric telegraph

Beverley F. Ronalds

Decades before the work of Samuel Morse, a young Englishman laid out his vision for a future world of telecommunication.



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It is 200 years since Francis Ronalds (1788–1873; shown in the portrait at left around age 80) first used electricity to transmit messages over long distances. Ronalds was in his twenties when he built his telegraph in 1816 in the back garden of his family's home alongside the River Thames in Hammersmith, London. A plaque commemorating the milestone was later installed on the house by the Institution of Electrical Engineers. Ronalds had gone on to assist in the establishment of electrical engineering as a profession and was regarded as the first practitioner of the new discipline.

In Ronalds's younger years, electricity was still a scientific curiosity, with little thought given to any application. Static electricity was observed in nature, generated by friction and measured with an electroscope. Alessandro Volta invented the electrochemical battery in 1800, and the striking mechanical and chemical effects it produced were explored with great interest. However, no theoretical framework, consistent terminology, or units of measurement were available to help explain the observations, nor was there any clear understanding of how static electricity and Volta's current were related.

Even with so little known about electricity, Ronalds wanted to put it to work:

Electricity, may actually be employed for a more practically useful purpose than the gratification of the philosopher's inquisitive research . . . it may be compelled to travel . . . many hundred miles beneath our feet . . . and . . . be productive of . . . much public and private benefit. . . . Let us have *electrical conversazione offices*, communicating with each other all over the kingdom.¹

He was foreseeing not only the electrical age and the industry that founded that new era, but also a world of electrical conversations somewhat similar to what we enjoy today. His words survive in a booklet entitled *Descriptions of an Electrical Telegraph, and of Some Other Electrical Apparatus*.¹ Printed in 1823 for private distribution, it was the first articulation of the possibilities of rapid global communication and the first detailed description of a working telegraph.

The 1816 demonstration

Ronalds brought his vision to life through both theoretical insight and practical design. To verify

that communication could be almost instantaneous even over long distances, he passed electric signals through a 13-km iron wire strung back and forth between insulated supports on two large wooden frames, as shown in figure 1. He then built a complete subterranean system in a trench 160 m long and 1.2 m deep running down the side of the long garden.

To isolate the buried wire, Ronalds used a form of insulation he had developed for his apparatus to collect and measure atmospheric electricity.² Its novelty was in enclosing the electrified wire in a narrow glass tube coated inside and out with sealing wax to minimize circulation of moist air. In the telegraph application, the tubes rested on small blocks in a trough lined with pitch. To keep moisture out while allowing the tubes to thermally expand and contract, Ronalds coated the junctions between tubes in soft wax and housed them in glass sleeves—perhaps the first use of sleeved expansion joints. Sections of the insulated line, unearthed by later owners of Ronalds's home, are held in several British museums.

As shown in figure 2, the demonstration incorporated a testing post, which would enable any failure to be located. The wire rose out of the ground, protected by an outer box, and the connection could be broken on either side of an electrometer to determine which section of the line was at fault.

Ronalds chose static electricity rather than current to power the telegraph—he wanted a reliable apparatus, and Volta's battery ran down quickly in use. To provide the charge with minimal manual intervention, he built an "influence machine," shown in figure 3, which used mechanical work to amplify a small initial charge by means of electrostatic induction across three circular plates. As one of the plates swung back and forth on the pendulum bob



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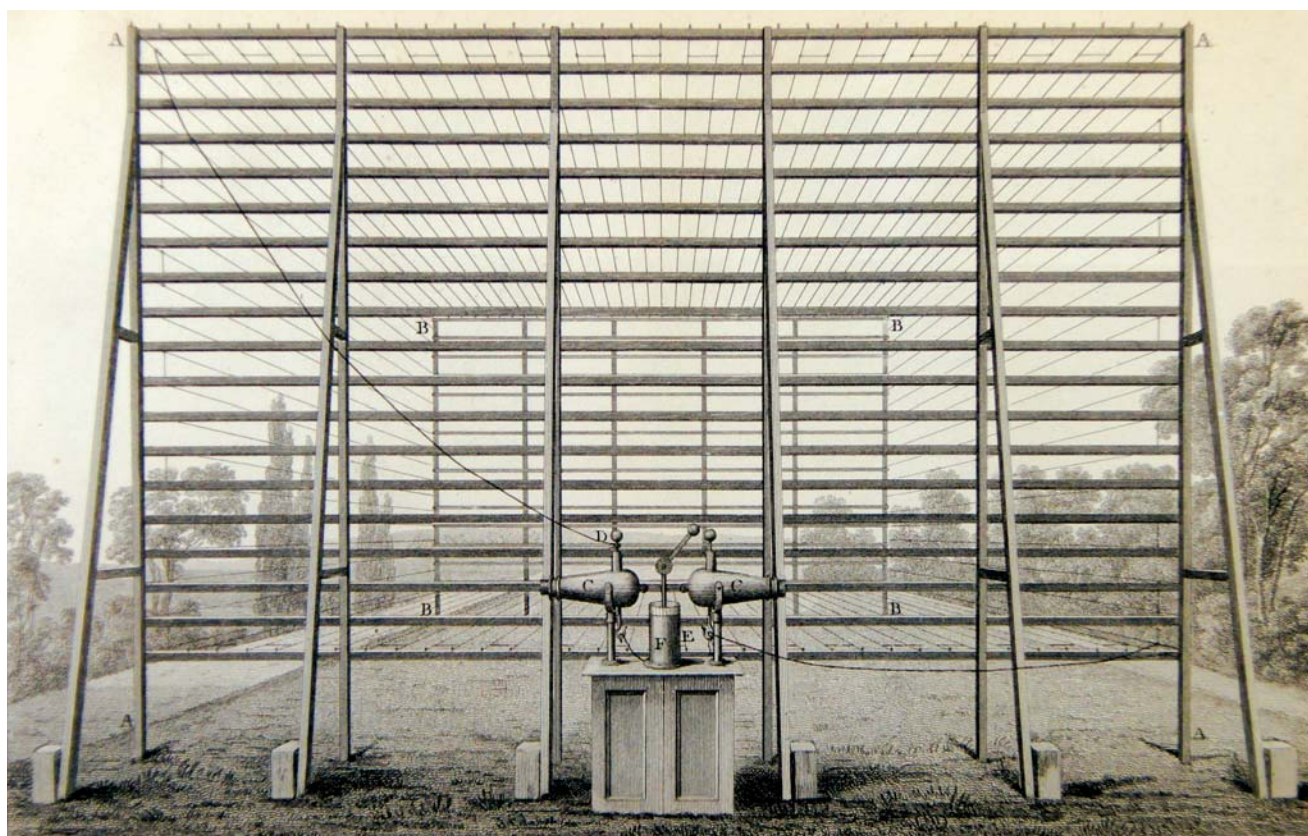


FIGURE 1. AN IRON TELEGRAPH WIRE, 13 km long, crisscrossing between two frames 18 m apart. In 1816 Francis Ronalds used the wire to demonstrate that electric signals could travel almost instantaneously over long distances. Many early telegraph systems used similar insulated overhead wires. (From ref. 1.)

of a timepiece, the plates were successively grounded and connected in a sequence that enabled charge to accumulate; the electricity was stored in a Leyden jar, an early form of capacitor. For full-scale operation, Ronalds suggested that the generator could be powered by a small steam engine instead of the clockwork mechanism. The apparatus was still described in textbooks late in the 19th century.³

Messages were transferred by means of synchronized dials. At each end of the wire, a circular brass plate turned with the second hand of a clock and was marked into 20 subdivisions, each having a letter, a digit, and a message helpful to the communication process, as shown in figure 4. A second, stationary plate with a slit covered all but one of the divisions. Each end of the wire was connected to an electrometer, also visible in figure 4. The wire was normally kept charged, so the two arms of the electrometer acquired like charges and diverged. When the sender grounded the wire momentarily, the electrometer's arms dropped, and the recipient recorded the information shown on the dial at that moment. The role of the electric signal was thus to communicate when to read the continuously rotating dial.

Ronalds developed a procedure for checking at the beginning of the communication that the two clocks were indeed synchronous. The sender overcharged the wire to explode a

gas pistol and alert the recipient to a forthcoming message and then signaled the message, "Prepare." The recipient adjusted the cover plate if necessary to agree with the known message, and then signaled back "Ready."

As a faster alternative to spelling out words, Ronalds conceived a message grid: a book with 10 numbered pages, each with a table of 10 columns and 10 rows. Each of the 1000 cells contained a simple message. The sender had only to signal a sequence of three numbers to let the recipient know which message to read.

Overall, it was a pioneering demonstration, although the system had weaknesses in comparison with later ones. The key disadvantages were noted in *Traité de Télégraphie Électrique* in 1849:

Mr. Ronalds would have completely solved the problem of telegraphy, if he had not had two fundamental obstacles; the difficulty of establishing the essential synchronism between the two clocks, and the inability to clearly identify what would succeed static electricity.⁴

Ronalds made a further important theoretical contribution to the telegraph in highlighting the risk of signal retardation. He realized that the wire, when insulated and buried, was "serving a like office to that of the interior coating of the Leyden Jar."⁵ An electric signal in the wire attracted opposite charge through the material outside the insulation—that is, it caused electrostatic induction—which slowed progress of the signal down the line. Nearly 40 years later, after several telegraph lines had failed, telegraph engineer Josiah Latimer Clark performed detailed experiments on long cables, and Michael Faraday used the same Leyden jar analogy to explain his observations.⁶

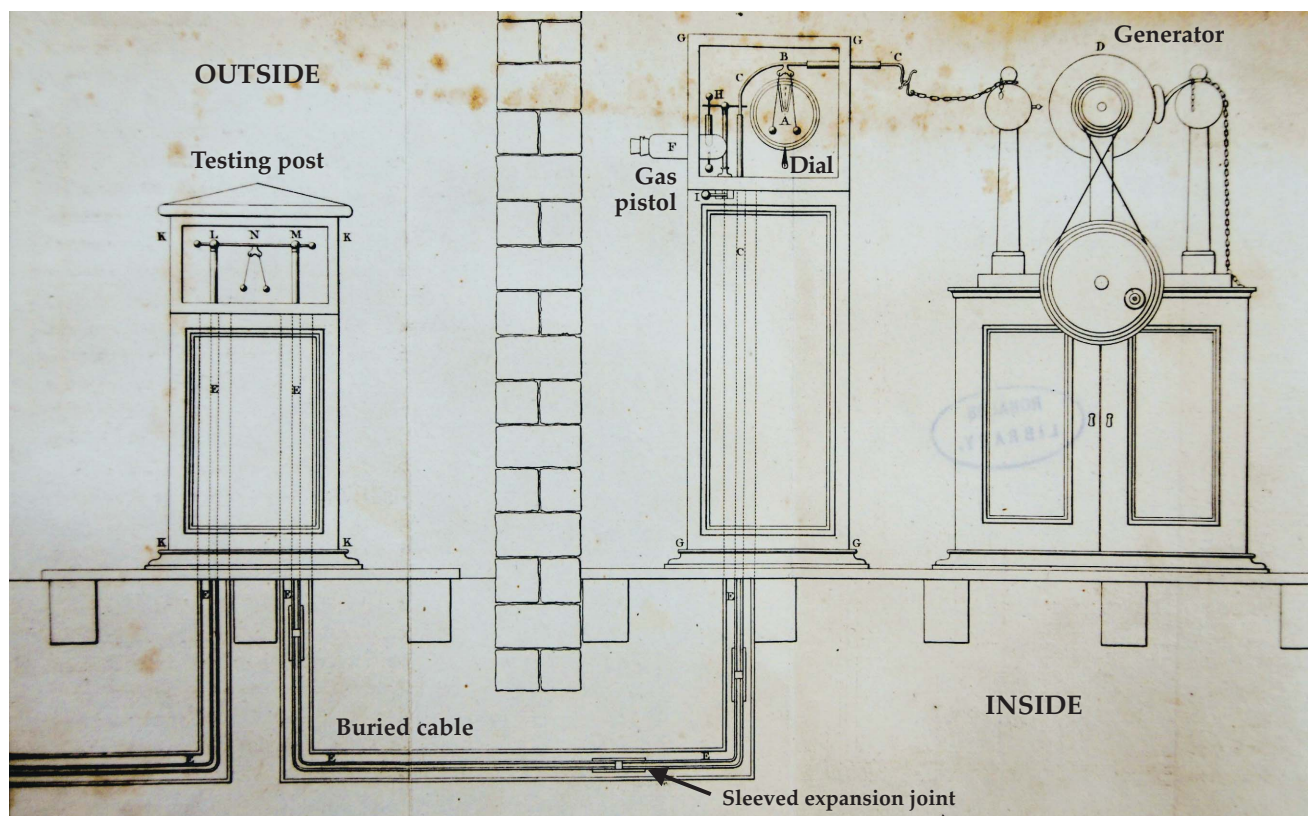


FIGURE 2. SUBTERRANEAN TELEGRAPH SYSTEM showing the interior and exterior components of Francis Ronalds's 1816 demonstration. Testing posts along the line allow any failure in the buried cable to be pinpointed and repaired. Ronalds recommended that the posts be placed "at *about* equal distances from each other" at "post-offices in towns and villages, turnpike-gates, &c. &c." The modern equivalent is still found on sidewalks today. (Adapted from ref. 1.)

Clark soon realized that their work had been preempted and excitedly introduced himself to Ronalds in 1861:

It is most interesting to me to see the phenomenon of "*retardation of current*" which has so greatly occupied the attention of Electricians of late years in connection with long Submarine Cables, distinctly foretold & described in your work published in 1823!⁷

Telegraph patents

Ronalds had no part in commercializing the telegraph. Instead, he offered his new invention to the government: The long war with France, which had just ended with the Battle of Waterloo in 1815, had highlighted the need for rapid communication in national defense. But on 5 August 1816, the admiralty advised him that a telegraph was "wholly unnecessary."⁷ The government was content to rely on the semaphore.² With such complete dismissal and no other potential market, Ronalds ceased work and left the field.

Commercialization of the electric telegraph awaited the appearance of a new client. In 1837 the first patent was taken out in England by William Cooke and his partner Charles Wheatstone. Samuel Morse filed a caveat that same year in the US, and his patent⁸ was granted in 1840. The designs were put into practice along the early railway lines, where they controlled train operations and were ultimately used to transmit general news and information.

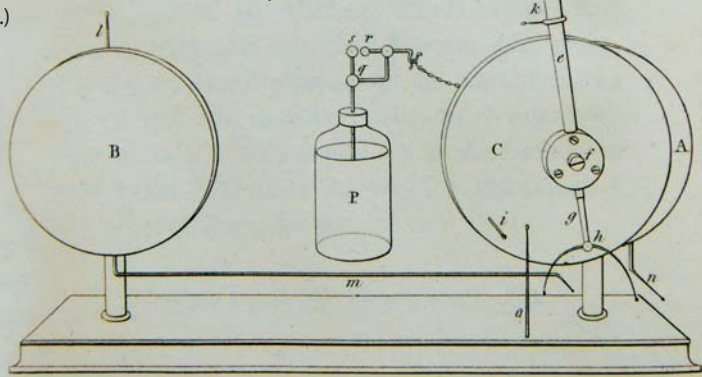
Cooke, Wheatstone, and Morse took advantage of important new discoveries in electrical science, beginning with Hans Ørsted's 1820 observation that electricity and magnetism were interrelated. The electromagnet, developed a few years later, enabled mechanical work to be done at a distance by applying a current. Electromagnets could be deployed as a relay switch to operate the telegraph receiver or in repeaters at intermediate wire locations to increase the transmission distance. In 1827

Georg Ohm published his famous law, which related electromotive force, current, and resistance and allowed circuits to be designed mathematically. Finally, John Daniell in 1836 created a battery much longer lasting and more reliable than Volta's pile. All the elements were available to put together a new generation of electric telegraphs powered by current rather than static electricity.

The three patentees were all aware of the work Ronalds had done. Morse's colleague Alfred Vail included the description of Ronalds's telegraph from the 1842 *Encyclopaedia Britannica* in his book *The American Electro Magnetic Telegraph*.⁹ Wheatstone had close personal knowledge of the demonstration, having apparently witnessed Ronalds's experiments, and Cooke was a family friend who had also operated the telegraph in Hammersmith.¹⁰

Several of Ronalds's concepts made their way into the new generation of technologies. Wheatstone and Cooke patented alphanumeric dials similar in overall configuration to the ones Ronalds developed, and dials were also used in early printing telegraphs. Working telegraphs incorporated the approaches Ronalds had recommended for cable protection, redundancy, and surveillance; they also used his testing posts for subterranean sections. The attention to practical design in Ronalds's booklet prompted more than one telegraph engineer in the 1870s to note that it "might almost serve for a description of a telegraphic system at the present day."¹¹ Indeed, the testing

FIGURE 3. AUTOMATED ELECTROSTATIC GENERATOR, or influence machine, with three insulated plates. Plates A and B are stationary, and plate C swings back and forth between them, driven by clockwork or a small steam engine. The plates are alternately grounded and electrically connected through wires h, i, k, l, m, n, and o in a way that quickly increases the total charge. The charge is stored in a Leyden jar P for use on the telegraph. Charge given to the Leyden jar's cap flows to the conductive inner lining, and the opposite charge accumulates through induction on the exterior metal coating. The charges remain for a considerable time after the jar is disconnected. (From ref. 1.)



posts—telephone junction boxes—seen today at regular intervals along sidewalks still have the same purpose.

A new profession

The UK had the foundation of a national telegraph network by 1848 and was linked with continental Europe in 1851. The first messages across the US were transmitted in 1861. A successful transatlantic link was in place in 1866, and Australia was connected to London via Singapore and India in 1872. Ronalds lived to see it all and followed progress with great interest. He felt little proprietorship over his ideas, although he did retain the belief that his original scheme was sufficiently practical to have been tested at scale. As he wrote in 1860:

[I] am very far from advocating the cause of static in lieu of *magnetic* electricity for telegraphic purposes . . . but I *will* say that if the electric telegraph of 1816 had been fairly examined, an *effective* instrument might have been in the hands of the government & that after Dr Ørsted's . . . experiments [in 1820] an *improved* telegraph might have been in the said hands [before Cooke's, Wheatstone's, and Morse's work]; also that messages [sic] might have been conveyed thereby as cheaply in England &c as they are in America "a'most."⁵

Ronalds had noted in his original booklet that technological improvements "in practice would undoubtedly suggest themselves to an intelligent engineer."¹ His view was that the admiralty's decision had postponed that gathering of experience and delayed the incorporation of both electricity and rapid communication into the industrial revolution.

The great triumph of a global telegraph system was marred by ongoing bickering among Wheatstone, Cooke, Morse, and Vail as to which of them was the actual inventor. Ronalds was different—he consistently emphasized the many contributions

others had made both before and after his 1816 work. Nonetheless, credit for the invention was gradually bestowed on him. Sir John Rennie, in his 1846 presidential address to the Institution of Civil Engineers, was perhaps the first engineering leader to refer to Ronalds as the inventor of the telegraph. In 1855 the secretary at the Royal Society advised Ronalds, who was living in Paris at the time:

Mr Cooke is at length making considerable stir respecting the Electric Telegraph and its introduction by him into England prior to Wheatstone—but I am glad to find your name honourably and very properly mentioned in the history. Mr C mainly attacks Mr W—other parties talk of you.⁷

By the 1860s the British scientific community widely acknowledged the importance of Ronalds's groundbreaking demonstration. (Doing so, incidentally, had the additional effect of helping to argue the UK's precedence over the US in the invention.)

The three Englishmen were all knighted between 1868 and 1870. Wheatstone received

his honor "in consideration of his great scientific attainments and of his valuable inventions,"¹² Cooke "for great and special services in connexion with the practical introduction of the electric telegraph,"¹³ and Ronalds as "the original inventor of the electric telegraph."¹⁴ Within days, Ronalds wrote to the *Times of London* disclaiming the descriptor. The knighthood nevertheless stimulated demand for his original booklet; the journal *Nature* noted that Ronalds "has done well in republishing this" when it was reprinted in 1871.

That same year, a professional body was founded in the UK to support the growing cohort of telegraph engineers. Ronalds was invited to join the Society of Telegraph Engineers (STE), which became the Institution of Electrical Engineers (IEE) in 1888 and is now the Institution of Engineering and Technology (IET). He wrote a short piece for the first volume of the STE's journal. The quality of his foundational work was acknowledged by the membership—an early president, William Preece, explained at one of the meetings that Ronalds's booklet "would do credit to any member of this Society if written in the year 1887. It is perfectly astonishing how that man's instinct saw the various troubles that were likely to be met with in the construction of long underground lines. . . . It is a pamphlet that is well worth studying by everybody here."¹⁵ Remarks by members of the STE and IEE, including Preece, Alfred Frost,¹⁰ and Rollo Appleyard,¹⁶ suggest that he was regarded as the first electrical engineer.

When Ronalds died in 1873, his extensive library of electrical works, considered to be the best in the world at the time, was bequeathed to the embryonic society and helped cement its future. His library catalog is referenced in *Origins of Cyberspace* (2002)¹⁷ as "the first bibliography pertaining to telecommunications" and was reprinted in 2013 by Cambridge University Press.¹⁰ Thus Ronalds not only pioneered electrical engineering as a young man but assisted the new profession at the end of his life.

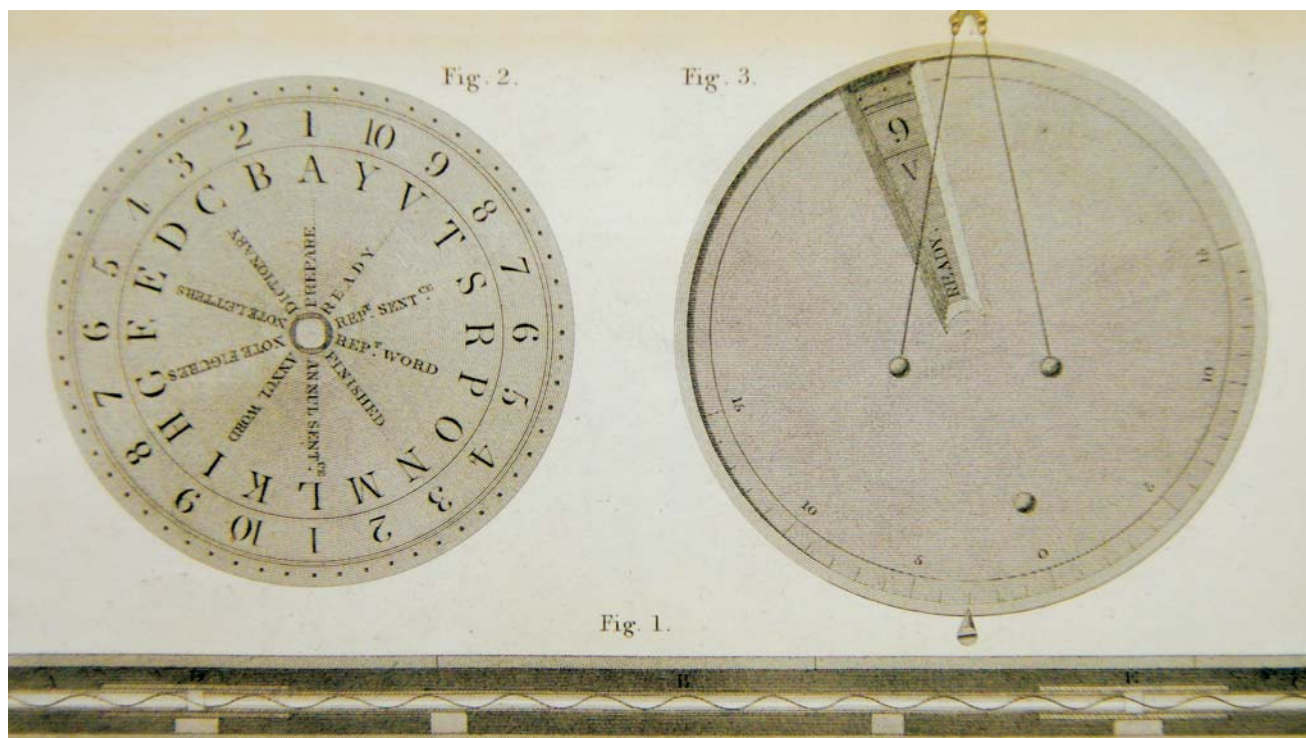


FIGURE 4. AN ALPHANUMERIC DIAL for transmitting messages. As the dial (left) turns at a constant rate, a single segment is visible through a stationary cover plate (right). When the dial is used as part of an electric telegraph, the electric signal tells the message recipient when to read the information on the dial. Similar dials were the basis for numerous subsequent alphanumeric and printing telegraphs and even early telephone systems. At the bottom of the figure is a detailed illustration of the insulated telegraph wire and sleeved expansion joint, which allows the glass insulation to thermally expand and contract. (From ref. 1.)

A full career

Ronalds made many other contributions to science and engineering, some of which were relevant to the telegraph. For a decade, he was director of the Kew Observatory near London, where his inventions included, in 1845, the first successful cameras to record the continuous modulation of meteorological and geomagnetic parameters 24 hours a day. While at Kew, he returned to his earlier studies of atmospheric electricity and developed another new method to electrically insulate his collecting rod: using a lamp to constantly heat the interior of the glass support and prevent moisture condensation. In today's par-

lance, he measured both the air-ground currents and the electric potential gradient through the air column in the global atmospheric-electricity circuit.

He was intrigued by the geomagnetically induced currents seen on telegraph lines in 1847–48, the first sunspot peak after the network had been built. He received data from telegraph operators to compare with his own observations of atmospheric electricity and terrestrial magnetism, his goal being “to elucidate a little the subjects of atmospheric electro-magnetism & the Aurora.”⁵ Electric currents induced by magnetic storms came to be understood in the 20th century and, though now managed with warning systems and protection mechanisms, they remain a risk to telecommunications systems.

Despite his vision, advanced understanding of electrical phenomena, and practical innovations, Francis Ronalds is little remembered today. It is timely at the bicentennial of his most noticed invention to acknowledge this talented and modest scientist and engineer.

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